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Food Security in the Context of Climate Change In Pakistan

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Abstract

The present study determines the impact of climate change on wheat production along with its per capita availability. The study is different from previous studies as it considers the irrigated and rain-fed regions of the Punjab province. Separate production functions are used for the irrigated and rain-fed regions. Tests for determining normality, linearity, autocorrelation and multicollinearity are also applied. Results show that in the irrigated region, rising maximum temperature during January and November has negative effect, whereas variables such as wheat area, minimum temperature during November and March are positively related with wheat production. Considering the rain-fed region, minimum temperature during February and November has significant impact on wheat production whereas rainfall in the month of March is negatively related with wheat production. Three different scenarios used to project future impact of temperature and rainfall on wheat indicate a decline in future per capita availability of wheat as a result of climate change, in addition to rising population in Pakistani Punjab. Considering an increase in temperature by 3^{o}C in 2050, per capita availability of wheat would be only 84 kg per annum compared to 198 kg per annum in 2012. So adaptation to climate change in the forms of new varieties and better management practices would lessen the impact of climate change.

Keywords: temperature, precipitation, food security, irrigated region, rain-fed, Punjab

1. Introduction

Food security has remained the foremost objective of the Government of Pakistan. Therefore, the policymakers spend substantial time on designing sound food policy leading to food security. Various factors have impact on food security including agronomic, institutional, political factors, in addition to climatic factors. Climate change is considered the most crucial factor influencing food security. Food security includes different dimensions, namely production, distribution and accessibility. Considering food production dimension, the studies show substantial impact of temperature and rainfall on food production (Mahmood et al., 2012; Janjua et al., 2010).

Wheat is the staple food crop in Pakistan and thus, food security policy mainly focuses on wheat production in the country. Farmers sow wheat in winter and harvest it in summer. Before the flowering stage, cold temperature accelerates wheat growth process because high temperature can cause a delay in the growth of seedlings. Rainfall can damage wheat production at the time of harvesting, ultimately leading to a threat to food security in Pakistan (Janjua et al., 2010). During the recent years, harsh weather conditions in Pakistan have affected adversely the supplies of agriculture production, particularly food crops and it is expected that food production will be threatened in the coming years as well (GFSI, 2012). Further, changes in temperature and rainfall during reproductive and vegetative stages are important in wheat production (Mitra & Bhatia, 2008; Semenov, 2009).

Some estimates show that wheat availability in the country has declined in the recent past (FAO, 2012, GOP, 2011). Per capita availability of wheat in Pakistan has an important position to achieve objective of sustainable food security. Although pricing system and regional trade strategies (Iqbal et al., 2005) have important policy concerns, climate change has significant impact on wheat production. This demands for determining impact of climate change on wheat production in the country.

Achieving goal of food security, especially for poor population becomes difficult as a result of climate change (Gregory et al., 2005; Rosegrant & Cline, 2003) coupled with other problems, such as rising population, shortage in water availability and land degradation. Further, climate change is also linked to a decline in crop productivity (Cline, 2007; Parry et al., 2005), thereby adversely affecting food security in Pakistan. Adapting to climate change can reduce the negative impact on agricultural productivity (Di Falco & Chavas, 2009).

This paper focuses on wheat production in the presence of climate change in Pakistan. Small farms in Pakistan dominate as they account for more than 90 percent in total farms (GOP, 2010) and food productivity is highly determined by these small farms. Punjab is the largest province of Pakistan with a contribution of around 80 percent in wheat production. Thus the present study estimates the effects of climate change on wheat production, being the staple crop of the country. The study is different from the previous studies conducted in Pakistan as it focuses on irrigated and non-irrigated i.e. rain-fed areas of the province. Farmers in the non-irrigated region are more vulnerable to climate change compared to irrigated region, since farming totally depends on climatic factors. Thus it is imperative to consider both regions separately in determining the effects of changing temperature and rainfall on wheat production.

2. Review of Literature

Different studies conducted in the world show significant impact of climate change on agriculture in general and wheat production in particular. Regions with massive grain production may have a negative effect due to increase in temperature. Further, crop production relies on the inter-regional adjustments of the region (Tobey et al., 1992). Wheeler & von Braun (2013) argue that short-term variability in food supply may have adverse effects on sustainability of food systems in the world under climate change scenario. Climate change can have devastating effect on already vulnerable and malnourished regions of the world. Qureshi et al. (2013) find negative impact of climate change on Australian food exports, indicating that global food security would be affected because of sustainable Australia's contribution to international trade in wheat, meat and dairy products. Hanjra & Qureshi (2010) examine linkages food security and global water supply and show that water availability for food security would decline to an alarming situation in the absence of right action. Investment in research, infrastructure development and conservation practices is suggested to reduce intensity of water shortage in the coming years.

Saseendran et al. (2000) shows that maturity period of crop can decline to eight percent and yield may decrease by six percent due to an increase in temperature. Rising temperature by one ^{o}C may cause 7.5 percent reduction in wheat productivity during growing periods. Peng et al. (2004) estimate rice productivity by considering weather and agronomic data from Philippines. Results indicate that 1°C increase in the minimum temperature during the growing season would lead to 10 percent decrease in the yield. Xiao et al. (2008) determine the effect of climate variability on wheat production at high altitude and find that crop yield increases during the period due to positive change in temperature and precipitation. Ye et al. (2014) find the similar findings. However, they indicate that food security will face major challenge due to increasing demand and regional disparities in China. Baldos & Hertel (2014) examine global food security in 2050 considering role of agriculture productivity and climate change. Results indicate that food security will increase as a result of increasing agricultural productivity but climate change will threaten food security due to CO_2 emission and its impact on crop yield.

Hussain & Mudasser (2007) assess the impact of climate change in Swat and Chitral regions of Pakistan and show that an increase in temperature up to 1.5^{o}C would enhance the yield by 14 percent in Chitral and decrease yield by 7 percent in Swat. Janjua et al. (2010) estimate the impact of carbon dioxide on wheat supply in Punjab. However, rainfall and temperature may have different impact in rain-fed and irrigated areas. So the need is to consider these regions separately.

The above-mentioned studies have measured the impact of climatic variables on various crops around the world. In Pakistan we find very few studies focusing on the impacts of climate change on wheat. Further, focus of the available studies is on individual crops such as wheat (Ahmad et al., 2012) and rice (Mahmood et al., 2012), ignoring mode of irrigation used in wheat production. Contribution of the present study is that it determines the impact of climate change on wheat production in Punjab region taking into account geographical variation. Separate econometric methods are employed to ascertain the impact of climate change on wheat supply in Punjab, Pakistan.

3. Materials and Methods

As wheat area and production is commonly concentrated in the Punjab province so we considered the province for the present study. The Punjab province contributes substantially in food security in Pakistan. Contribution of Punjab in wheat production in Pakistan is well above 80 percent. We used time series data from 1980 to 2012 from different issues of Punjab Development Statistics, Agricultural Statistics of Pakistan and Economics Survey of Pakistan. Data on climatic variables were collected from the Pakistan Meteorological Department. We considered various climatic variables in the present study. They are rainfall and temperature including minimum and maximum.

3.1 Econometric Analysis

The aim of the study is the estimation of the effects of climate change on wheat supplies in the irrigated and non-irrigated regions. We used a linear production function for irrigated region and nonlinear form for the non-irrigated region of Punjab. Linear functional form was also used by McCarl et al. (2008). The dependent variable for the present study is production (thousand tonnes) of wheat. Independent variables considered in the production function are area allocated to wheat crop and the climatic variables including temperature and rainfall. General form of production function used in the study is as under:

$$Y_t(\text{wheat prod}) = \alpha_o + \beta_o(\text{Area})_t + \beta_1(\text{Temperature})_t + \beta_2(\text{Rainfall})_t + \mu_t$$

Where Y_t represents the production of wheat. $(\text{Area})_t$, $(\text{Temperature})_t$ and $(\text{Rainfall})_t$ are the area allocated to wheat crop, temperature and rainfall, respectively. μ_t is error term and t is years ranging from 1 to t. Several forms of production function were used. However, the linear form is selected for the present study on the basis of scatter diagrams of explanatory variables as these diagrams show linear relationship between dependent and explanatory variables.

As mentioned earlier, separate production function is used for irrigated and rain-fed regions, first we discuss production function for irrigated region that is given as under:

$$Y_t = \alpha_0 + \beta_0 X_1 + \beta_1 X_2 + \beta_2 X_3 + \beta_3 X_4 + \beta_4 X_5 + \beta_5 X_6 + \beta_6 X_7$$

Where Y_t is total wheat production (thousand tonnes) in irrigated region of Punjab. X_1 is area (thousand hectares) under wheat crop in irrigation region, X_2 and X_3 are the maximum temperature (^{o}C) in January and November respectively. X_4 and X_5 are the minimum temperature (^{o}C) in November and March respectively. X_6 is rainfall (mm) in February and X_7 shows square of rainfall (mm) in the month of February. α_o, β_1, β_2, β_3, β_4, β_5, β_6 and β_7 are the parameters to be estimated.

Production function used for rain-fed region is as follow:

$$Y_t = \alpha_o + \beta_o X_1 + \beta_1 X_2 + \beta_2 X_3 + \beta_3 X_4 + \beta_4 X_5 + \beta_5 X_6 + \beta_6 X_7 + \beta_7 X_8 + \beta_8 X_9 + \beta_9 X_{10} + \beta_{10} X_{11}$$

In rain-fed region Yt is considered as a total wheat production (thousand tones) in the rain-fed area. X_1 and X_2 are the total area (thousand hectares) and square of area. X_3 shows the minimum temperature (^oC) of November and X_4 shows the square term. X_5 is the maximum temperature (^oC) in January. X_6 and X_7 represent the minimum temperature (^oC) of February and its square respectively. X_8 and X9 represent the rainfall (mm) in February and its square. X_{10} and X_{11} are the rainfall (mm) in March and its square. The remaining terms are the parameters to be estimated.

4. Results and Discussion

We employ Q-Q plot to determine normality and results show that our variables fulfill normality assumption. Another assumption is linearity and we use scatter plot of observed vs. predicted values and these plots also show that linearity assumption is satisfied. So we use linear regression analysis for determining wheat production for the irrigated region of Punjab, Pakistan. Value of Durban-Watson is close to two, indicating that there is no sever autocorrelation. Further, we use Variance Inflation Factor (VIF) and Tolerance to determine multicollinearity. Result show that value of VIF is below three for all variables considered in the analysis. Similarly value of tolerance is close to one. All these values show that multicollinearity does not exist among the variables considered. Among seven independent variables in the production function, we find four variables statistically different from zero at one percent level of significance and two variables statistically significant at ten percent probability level. Results show that an increase in wheat area is positively related with wheat production. Results also indicate that climatic variables such as maximum temperature in the months of November and January are negatively related to wheat production. Considering minimum temperature in the months of November and March, wheat production is positively affected. This may be due to the reason that, wheat crop requires minimum temperature for vegetative growth during November. Minimum temperature during March is considered better for grain formation. Rainfall in the month of February is found to be negatively related to wheat production, although statistically non-significant (Table 1).

Table 1: Results of OLS for the Irrigated Punjab

Variable	Coefficient	Standard error	t-ratio
Constant	-12548.69***	5263.913	-2.38
Wheat area	4.12***	0.47	8.76
Max. temperature during	-237.38	187.13	-1.27
Max. temperature during	-306.84**	154.25	-1.99
Min. temperature during	731.054***	229.09	3.19
Min. temperature during	605.86***	196.97	3.08
Rainfall during February	-75.53	46.52	-1.62
Square of rainfall during	0.830	0.6132	1.35
R^2	0.95		
F-value	72.. 3		
Durban Watson	1.99		

***, ** and * shows level of significance at one, five and ten per cent respectively.

Contrary to the wheat production in irrigated region, we use nonlinear functional form to determine impact of climatic variables on wheat production in the rain-fed region. Results show that the value of Durban Watson is close to 2, there is no autocorrelation problem. Likewise the value of F statistics is also statistically different from zero, indicating that overall regression model used is appropriate. Detailed description of explanatory variables is given in Table 2.

Out of 11 variables, there are four variables, being significant at one percent probability level, three are statistically significant at five percent and only one variable is significant at 10 percent significant level. Coefficient of area allocated to wheat is found to be positive and significant, indicating that when area of wheat increases, wheat production would also increase and its square term indicates that the increase in production is increasing at a decreasing rate.

Table 2: OLS Results of Wheat Production In Rain-Fed Punjab

Variable	Coefficient	Standard error	t-ratio
Constant	-3156.44**	1433.14	-2.20
Wheat area	15.71***	3.29	-4.28
Square of wheat area	-0.01***	0.0002	-4.28
Min. temperature during	-422.57**	181.31	-2.33
Sqr. min. temperature	20.43**	8.84	2.31
Max. temperature during	-63.85**	28.88	-2.21
Min. temperature during	153.95***	39.70	3.88
Sqr. Min. temperature	-3.64***	1.08	-3.57
Rainfall during February	4.15	2.94	1.41
Sqr. Rainfall during	-0.02	0.02	-1.16
Rainfall during March	-3.67*	2.02	-1.82
Sqr. Rainfall during	0.01	0.001	1.04
R^2	0.72		
F-value	4.75		
Durban Watson	1.98		

***, ** and * show level of significance at one, five and ten per cent respectively

Mean minimum temperature in the month of November has negative impact on wheat production because wheat requires comparatively high temperature at the time of sowing. The negative sign of square of minimum temperature during November shows that marginal effect on wheat production is declining. Minimum temperature during February is positively associated with wheat production along with significant and negative coefficient of its square term. Maximum temperature of January has negative effect on wheat production in rain-fed region, implying that wheat production will be affected by increased maximum temperature during this month as rising temperature negatively affects vegetative growth of wheat crop (Table 2).

4.1 Impact of Climate Change on Wheat Production in Irrigated Region

In order to determine the future effects of climate change in irrigated area on wheat production, we use three different scenarios of temperature and rainfall. In the first scenario, it is considered that there is no effect of temperature over the time period under consideration. The second scenario shows that temperature would rise over the year 2050 from 1.5 to 3.0^0C (IPCC, 2001). Lastly, third scenario is linked with change in rainfall.

According to the results of these three scenarios, wheat production under irrigated area has increased. As temperature rises by 0.3^0C it would also raise the production by 0.4 percent. Regarding scenarios of changes in rainfall, 5 mm rise in the rainfall may raise the total wheat production by 0.06 percent whereas 5 mm decrease in the rainfall will decrease the production by 0.06 percent.

4.2 Relationship between Climate Change and Wheat Production in the Non-Irrigated Region

The same scenarios mentioned in the above section are considered for the rain-fed region as well. Results show that as temperature increases by 0.3^0C it would increase the productivity by 6 percent. Considering rainfall variations, 5mm increase in the rainfall is found increasing crop production by 0.21 percent whereas 15 mm is associated with an increase in wheat production by 0.62 percent and 5 to 15mm declining rainfall would result in a decreased production by 0.21 to 0.62 percent.

4.3 Per Capita Wheat Availability in the Punjab Province

We estimated wheat availability on per capita basis over different time periods using climate change scenarios. As the impact of temperature on wheat production is found to be significant in both the regions, it does not provide a relieving situation. Considering current growth rate, it is expected that population of the province would increase many times in future. As a consequence of rising population, there would be significant impact on food security because wheat is a staple crop in Pakistan. Table 3 shows comparison of wheat production and its per capita availability in Punjab, Pakistan.

Table 3: Projected Per Capita Wheat Availability in Changing Temperature

Years	Wheat production (000 tons)	Punjab population (million)	Per capita availability (Kg)
2012	19041	96.3	198
2021	13478	110.8	122
2031	13387	126.9	105
2041	13296	143.1	93
2050	13206	157.6	84

Rising population threatens food security. Results indicate that currently per capita wheat availability is 198 kg per annum and it would be 105 kg per annum in 2031 and 84 kg per annum in 2050 (Table 3).

For rainfall scenarios, we find that production of wheat crop would increase with increased rainfall in the coming years. It would increase per capita availability of wheat in the province. However, we find that a decline in rainfall would decrease wheat production. Consequently, per capita availability would also decrease. Results in Table 4 show that there is an increase in population and wheat production with the passage of time, considering increase in rainfall scenario. However, per capita availability of wheat would decrease. Considering a decrease in rainfall scenario in the province, per capita availability of wheat is found to be 198 kg per annum in 2012 and it would be 107 kg per annum in 2031 and only 86 kg per annum in the year 2050 (Table 4).

Table 4: Projected Per Capita Availability of Wheat Considering Change in Rainfall Scenarios

Scenarios	**Years**	**Wheat Production (000 tons)**	**Punjab Population (million)**	**Per Capita Availability (Kg)**
Increase in rainfall	2012	19041	96.3	198
	2021	13656	110.8	123
	2031	13666	126.9	108
	2041	13676	143.1	96
	2050	13687	157.6	87
Decrease in rainfall	2012	19041	96.3	198
	2021	13635	110.8	123
	2031	13624	126.9	107
	2041	13614	143.1	95
	2050	13610	157.6	86

5. Conclusion and Recommendations

The study determined the effect of changing climatic conditions on wheat crop in the irrigated and non-irrigated regions of Punjab, Pakistan. Results showed that wheat production would increase in the irrigated region in spite of changing climate. However, we found negative effect of climatic variables on crop production in the rain-fed region. The reason is that crop production depends on climatic factors, therefore, changes in rainfall and temperature are significantly related with wheat production. Based on climate scenario and population in the coming years, it was found that per capita availability of wheat in the province would decline. It is due to two factors. One is the rising population and the second one is adverse effect of changing climatic conditions on wheat crop.

The emergent need is to develop wheat varieties having adaptive capacity to climate change conditions because changing climatic conditions would play an important role in determining future wheat yield. Important factors in increasing wheat supply include farm management practices and adoption of technology. There is a need to educate farmers in using new varieties having adaptive capacity to climate change and crop management practices, ultimately leading to get higher crop income from the land. To achieve this end, extension staff can arrange training programs for farmers. Making more investment in agriculture would increase food security in the country. High investment in agriculture would provide food security if investment in research and development is given more emphasis.

REFERENCES

Ahmad, M., Iqbal, M., & Samad, G. (2012). Climate change, agriculture and food security in Pakistan: adaptation options and strategies. [Online] Available: www.pide.org.pk/pdf/Broucher-Climate%20Change.pdf.

Baldos, U. L. C., & Hertel, T. W. (2014). Global food security in 2050: The role of agricultural productivity and climate change. *Australian Journal of Agricultural and Resource Economics,* 58(1), 1-18.

Cline, W. R. (2007). Global warming and agriculture. Impact estimates by country. Washington DC: Center for Global Development and Peter G. Peterson Institute for International Economics.

Di Falco, S., & Chavas, J. P. (2009). On crop biodiversity, risk exposure and food security in the highlands of Ethiopia. *American Journal of Agriculture Economics,* 91(3), 599-611.

FAO. (2012). *FAOSTATS, Food and Agriculture Organization of the United Nations*. [Online] available: http://faostat.fao.org

GFSI. (2012). Global food security index. An assessment of food affordability, availability and quality. A report from the Economist Intelligence Unit.

GOP. (2010). Agriculture Statistics of Pakistan 2009-10. Economic Wing, Ministry of Food Agriculture, Islamabad, Pakistan.

GOP. (2011). Agriculture Statistics of Pakistan 2010-11, Economic Wing, Ministry of Food Agriculture, Islamabad, Pakistan.

Gregory, P. J., Ingram, J. S. I., Campbell, B., Goudriaan, J., Hunt, L. A., Landsberg, J. J., Linder, S., Stafford, S. M., Sutherst, R. W., & Valentin, C. (2005). Managed production systems. In the Terrestrial biosphere and global change: Implications for natural and managed systems. Ed. B. walker, W. Steffen, J. Canadell, J. Ingram, 229-270. Cambridge, UK, University Press.

Hanjra, M. A., & Qureshi, M. E. (2010). Global water crisis and future food security in an era of climate change. *Food Policy,* 35(5), 365-37.

Hussain, S. S., & Mudasser, M. (2007). Prospects for wheat production under changing climate in mountain areas of Pakistan–An econometric analysis. *Agricultural Systems,* 94(2), 494–501.

IPCC. (2001). Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, PP. 881.

Iqbal, N., Bakhsh, K., Maqbool, A., & Ahmad, A. S. (2005). Use of the ARIMA model for forecasting wheat area and production in Pakistan. *Journal of Agriculture and Social Sciences,* 2(1), 120–122.

Janjua, P.Z., Samad, G., & Khan, N. U. (2010). Impact of climate change on wheat production: a case study of Pakistan. *The Pakistan Development Review*, 49(4), 799-822.

Mahmood, N., Ahmad, B., Hassan, S., & Bakhsh, K. (2012). Impact of temperature and precipitation on rice productivity in rice-wheat cropping system of Punjab province. *The Journal of Animal and Plant Sciences*, 22(4), 993-997.

McCarl, B. A., Villavicencio, X., & Wu, X. (2008). Climate change and future analysis: Is stationary dying? *American Journal of Agricultural Economics*, 90(5), 1241-1247.

Mitra, R., & Bhatia, C. R. (2008). Bioenergetic cost of heat tolerance in wheat crop. *Current Science,* 94(8), 1049-1053.

Parry, M., Rosengweig, C., & Livermore, M. (2005). Climate change, global food supply and risk of hunger. *Philosophical Transactions of the Royal Society B: Biological Sciences,* 360(1463), 2125-2138.

Peng, S., Huang, J., Sheehy, J., Laza, R. C., Visperas, R. M., Zhong, X., Centeno, G. S., Khush, G. S., & Cassman, K. G. (2004). Rice yields decline with higher night temperature from Global Warming. *Proceedings of the National Academy of Sciences of the USA*, 101(27), 9971–9975.

Qureshi, M. E., Hanjra, M. A., & Ward, J. (2013). Impact of water scarcity in Australia on global food security in an era of climate change. *Food Policy*, 38(1), 136-145.

Rosegrant, M. W., & Cline, S. A. (2003). Global food security challenges and polices. *Science*, 302(5652*)*, 1917-1919.

Saseendran, S. A., Singh, K. K., Rathore, L. S., Singh, S. V., & Sinha, S. K. (2000). Effects of climate change on rice production in the tropical humid climate of Karela, India. National Centre for Medium Range Weather Forecasting, New Delhi—110003, India.

Semenov, M. A. (2009). Impacts of climate change on wheat in England and Wales. *Journal of Research and Social Interface,* 6(33), 343–350.

Tobey, J., Reilly, J., & Kane, S. (1992). Economic implication of global climate change for world agriculture. *Journal of Agricultural and Resource Economics,* 17(1), 195–204.

Wheeler, T., & von Braun, J. (2013). Climate change impacts on global food security. *Science*, 341(6145), 508-513.

Xiao, G., Zhang, Q., Yao, Y., Zhao, H., & Wang, R. (2008). Impact of recent climatic change on the yield of winter wheat at low and high altitudes in semi-arid northwestern China. *Agriculture, Ecosystems and Environment,* 127(1-2), 37–42.

Ye, L., Tang, H., Wu, W., Yang, P., Nelson, G. C., Mason-D'Croz, D., & Palazzo, A. (2014). Chinese food security and climate change: Agriculture futures. *Economics: The Open-Access, Open-Assessment E-Journal*, *8*(1), 1-39.